Automated Droplet Manipulation through Electrowetting on Dielectric for DNA Synthesis

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ASMC Advanced Semiconductor Manufacturing Conference

Project Objectives

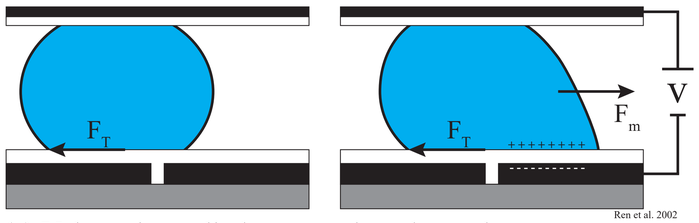
- Design an electrowetting on dielectric (EWOD) device that supports droplet manipulation and is also compatible with common cleanroom fabrication methods
- Perform and automate droplet manipulation with key functions such as droplet creation at reservoirs and merges at filters
- Characterize particle filtration performance

Motivation

"DNA RNA Oligo Synthesizer - Dr. Oligo." [Online].

- Nucleotides are essential for biological applications such as genetic testing, research, and forensics
- Modern synthesis tools are large, expensive, exhibit high power consumption, and have prototyping difficulties
- EWOD devices can be small, cheap, low power, easy to prototype for various custom applications

Electrowetting Theory



Ren et al. 2002

(a) Voltage is applied to actuation electrode
(b) Charge is induced in overlapping region of the droplet
(c) Electrostatic force deforms the droplet, reducing the liquid solid surface tension at the leading edge
(d) Surface tension gradient forces the droplet forward

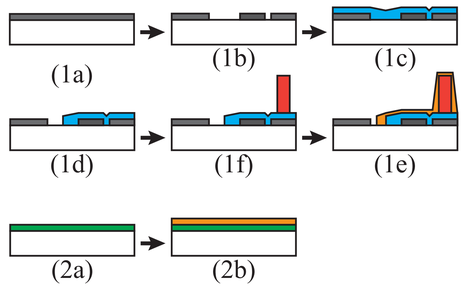
$$F_m = \frac{\varepsilon_0 \varepsilon_R}{2d} V^2 - F_T$$

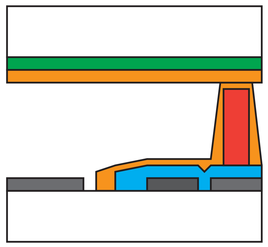
F_m: external force per unit length, ε_0: permittivity of free space, ε_R: relative permittivity of the entire film stack, d: gap distance between the top and bottom electrodes, V: applied voltage, and F_T: threshold initiation force

Device Fabrication

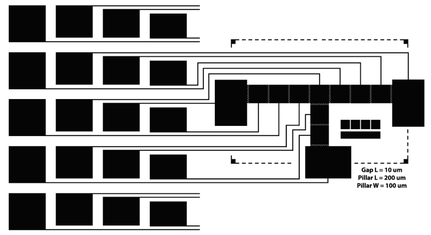
(1) Device Fabrication
- (a) Al electrode PVD
- (b) Electrode patterning
- (c) SiO_2 insulator CVD
- (d) Insulator patterning
- (f) SU-8 filter lithography
- (e) Teflon coating

(2) Top Plate Fabrication
- (a) ITO PVD
- (b) Teflon coating



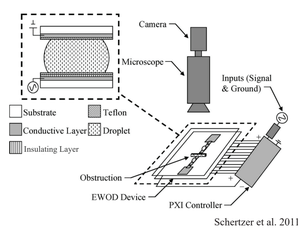


Device cross section

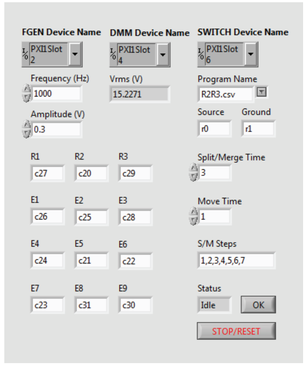


Top-down view of electrode design

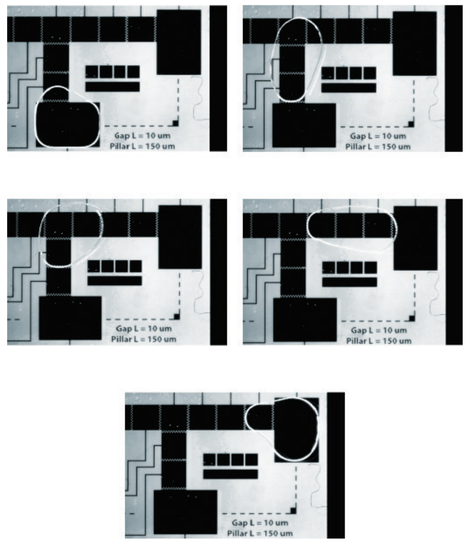
Automated Droplet Manipulation



Schertzer et al. 2011



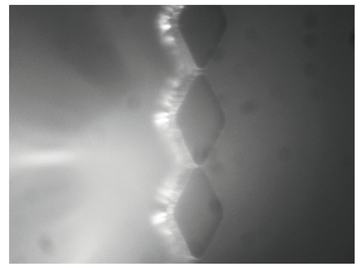
Comprehensive LabVIEW program was created for fully automated manipulation of droplets on device



- Electrowetting actuation conducted using 1 µL of DI water with an applied potential of ~38 V_{rms}
- Droplets were easily manipulated for various movement programs

Filter Fabrication

- SU-8 mechanical filters are fabricated using photolithography
- Filters are mechanically robust with a very small gap to be able to separate biological particles from carrier droplet
- Similar electrowetting actuation across device is ensured using filters as stand-offs



118 µm thick pillars with ~4 µm gap

Conclusions

- All the necessary components for a complete DNA synthesis EWOD platform was designed, fabricated, and tested for functionality
- While large droplets were easily able to be moved, small droplets could not be created from fluid at the reservoirs
- A better understanding of the droplet movement dynamics will improve future iterations in device design and automation development
- Automated functions such as droplet creation and merges must be perfected before filtration characterization

Acknowledgements

- SMFL Staff
- MicroE Department
- RIT DMFL
- Nuclera Nucleics

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MicroE Microelectronic Engineering
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